# Pavement Management dTIMS Model 2

This document was created as a revision of the original "Pavement Management dTIMS Model". It is intended to document the substantial changes that have been made to the original pavement management model contained within the dTIMS management system, as well as UDOT's overall pavement management philosophy and system.

Our Pavement Preservation program is a network level, long-term strategy comprised of several elements that work together to improve pavement performance and extend pavement life. The following paragraphs describe these Pavement Preservation elements.

**Routine Maintenance**

These are the planned day-to-day efforts to maintain and preserve the pavement condition at a satisfactory level. This involves crack filling, patching, isolated overlays, grading shoulders, maintaining roadside drainage, pavement markings, delineation, signing, lighting and landscaping. These efforts are typically performed with State forces using Code 1 funds (funds set aside specifically for these activities).

**Preventive Maintenance**

These are the efforts to improve the functional pavement condition and extend the service life. These activities are focused primarily on the surface of sound pavements in good condition. This involves treatments such as crack sealing, chip seals, slurry seals, micro surfacing, open graded surface courses, stone matrix asphalt overlays, thin hot mix asphalt overlays, lane leveling, concrete joint sealing, diamond grinding, dowel-bar retrofit, and isolated partial or full depth slab repairs. These treatments typically take place through UDOT's Orange Book and Purple Book programs.

**Pavement Rehabilitation**

These are the efforts that address structural enhancements that extend the service life and/or improve the load carrying capacity. This is typically categorized as *Minor* or *Major* rehabilitation.

Minor rehabilitation addresses the restoration of structural capacity due to age-related environmental cracking. Treatments are typically rotomilling and replacement; using a thin (2") structural hot mix asphalt overlay, or hot or cold recycling to replace the rotomilled pavement.

Major rehabilitation consists of structural enhancements that both extend the service life and improve its load-carrying capacity. Pavement thickness is increased to provide additional strength to accommodate existing or projected traffic loadings. Treatments are typically rotomilling and overlay; using hot or cold recycling, or hot mix asphalt overlays to increase the overall pavement thickness by at least 2 inches. These treatments are placed outside the category of "Pavement Preservation" since they are focused on increasing the pavement structure. These treatments typically take place through UDOT's Purple Book and Blue Book programs.

Other activities also outside the category of "Pavement Preservation" include:

**Corrective (Reactive) Maintenance**

These treatments respond to immediate concerns of pavement integrity or safety. They restore the pavement to a serviceable level that occurred due to unforeseen conditions. This involves pothole patching, edge drop off grading and isolated concrete slab replacements. These efforts are typically performed with State forces using Code 1 funds.

**Pavement Reconstruction**

This treatment is used to replace the entire pavement structure with equivalent or increased pavement thickness. This is required when the pavement has failed or become functionally obsolete. This treatment can be performed with either recycled or new materials. This treatment is typically performed through UDOT's Blue Book program.

UDOT's Pavement Management dTIMS model identifies asphalt and concrete pavement treatments within the Preventive Maintenance, Pavement Rehabilitation and Pavement Reconstruction categories.

**Pavement Families**

As with UDOT's original pavement management model, the pavements were divided into pavement families. This is intended to group pavements that perform in a similar fashion and can also have treatments that are triggered at similar conditions. UDOT's pavement network is stored in a program called the Plan For Every Section (PFES), which tracks planned treatments to the system on a section-by-section basis. The network is stored as sections of roadway based upon historical construction/maintenance activities. Each section is then classified as one of the various pavement families. The modeling takes place in a separate program called dTIMS, which is used by the central Pavement Management Unit to forecast pavement deterioration and come up with future pavement management strategies that optimize the system level condition and maximize the benefit-cost. The initial pavement management model contained six pavement families that have now been expanded to nine families including gravel. These families were based upon pavement type, functional classification and speed. As our data collection continues to improve, our pavement families may also continue to change. We are currently using the pavement families that are listed below:

0. Gravel
1. Interstate Concrete
2. High Speed Concrete (>50 mph)
3. Medium Speed Concrete (40 to 50 mph)
4. Low Speed Concrete (<40 mph)
5. Interstate Asphalt
6. High Speed Asphalt (>50 mph)
7. Medium Speed Asphalt (40 to 50 mph)
8. Low Speed Asphalt (<40 mph)

**Performance Curves**

Performance curves are curves/equations that predict how various pavements will perform over time based upon certain pavement characteristics and due to certain pavement distresses. These curves assume a “do nothing” strategy, meaning that only routine maintenance activities will occur over the pavement’s lifetime. Four basic “do nothing” performance curves were chosen for UDOT’s pavement management model.

UDOT has chosen to use the method of Dr. Gilbert Baladi from the Department of Civil Engineering at Michigan State University for representing pavement condition using condition indices on a zero to one hundred scale. In our pavement management model, the condition of 50 has been chosen to represent the point at which the Maximum Allowable Extent (MAE) has been reached (meaning that the pavement *for that distress* is in poor condition). This concept will be further discussed in the section labeled “Condition Indices”.

UDOT’s performance curves are simple quadratic curves based upon the design life of the pavement, using a zero to one hundred scale to represent condition. For example if the design life of the pavement is chosen to be 30 years, the initial points of (0,100) (representing a brand new pavement) and (30, 50) (representing the effective design life) are known. If the curve is assumed to be quadratic in shape, the equation can then be calculated as follows:

Present Condition = 100 – x (age)**2, where x = (100-50)/(design life)**2

*For design life = 30,*

50 = 100 – x (30)**2, => x = (100-50)/(30)**2 = 0.0556

*And a performance curve equal to the following:*

Present Condition = 100 – 0.0556 (age)**2

The chosen curves for UDOT’s pavement management model are based upon design lives of 30, 35, 40 and 45 years, respectively. We have chosen to give the performance curves a much less drastic shape once the effective design life has been reached. We have chosen to deteriorate the pavement at a rate of either 2:1 or 1.5:1, once the effective design life has been reached.

It should be noted below that in the area of roughness, asphalt pavements were assigned a longer life span than concrete pavements. It may seem counter intuitive that asphalt pavements were assigned a longer life span, because in general, concrete pavements will last longer. The decision makers at UDOT noted that the main pavement distress associated with properly designed concrete pavements with dowel bars was roughness. It was also noted that once significant roughness had occurred in either concrete or asphalt, the deterioration rate (as far as roughness) was much faster for concrete than asphalt (due to the rigid nature of concrete pavements). This discussion led to their respective “do nothing” design lives for roughness.

***30-Year Design Life***

This is the standard performance curve for most asphalt pavements. UDOT uses this curve to model environmental cracking, rutting and wheel-path (fatigue) cracking over time. The equation is as follows:

For years 0-30 => 100 – 0.0556 (age)**2 and for years 30+ => 49.96 – 2 (age-30)

***35-Year Design Life***

This is the performance curve that is used to model the pavement deterioration of IRI (roughness) for concrete pavements. The equation is as follows:

For years 0-35 => 100 – 0.0408 (age)**2 and for years 35+ => 50.02 – 2 (age-35)

***40-Year Design Life***

This is the standard performance curve for most concrete pavements. UDOT uses this curve to model concrete cracking, faulting and joint spalling over time. The equation is as follows:

For years 0-40 => 100 – 0.0313 (age)**2 and for years 40+ => 49.92 – 1.5 (age-40)

***45-Year Design Life***

This is the performance curve that is used to model the pavement deterioration of IRI (roughness) for asphalt pavements. The equation is as follows:

For years 0-45 => 100 – 0.0247 (age)**2 and for years 45+ => 49.98 – 1.5 (age-45)

**Condition Indices**

As briefly explained above, UDOT chose to model the deterioration of its pavements using condition indices according to the “Baladi Method”. This method is based on the idea of a Threshold Value (TV) and a Maximum Allowable Extent (MAE) that allow you to represent the condition of a pavement on a 0-100 scale. It was decided to use a threshold value of 50 to represent the boundary between fair and poor condition. This would signal the end of the effective design life for that particular distress, meaning that some treatment would be triggered to restore “life” to the pavement. The MAE represents the condition that defines the pavement as in poor condition (i.e. rutting equal to 1.25 inches). So, for each pavement distress MAEs needed to be defined for each pavement family. Through discussion other boundary points were also defined: 90 (very good/good), 70 (good/fair), 50 (fair/poor) and 30 (poor/very poor).

Indices were created for both concrete and asphalt. Also, a composite index was created within the model for two main purposes: the first purpose was to allow the model to optimize the system level performance based on all the indices combined rather than on one individual common index (RIDE) and the second purpose was to provide an initial comparison of the overall state any one pavement section with the overall state of any other section. The indices chosen and their equations are listed below.

***Concrete Indices***

The following indices were developed for concrete pavements:

RIDE: Roughness based on IRI (average of the left and right wheel path measurements)
CONK: Structural cracking from corner breaks (CBRK) and shattered slabs (SHSL)
FALT: Faulting (difference in slab elevation)
JTSP: Joint spalling

***RIDE*** (Roughness) – This is a measure of the driver's comfort when traveling down the road. It is measured using a profile van to calculate the IRI (International Roughness Index) for a roadway segment. The IRI used by UDOT is an average of the left and right wheel path measurement of roughness in inches per mile. Higher values indicate a rougher road. The equations for RIDE are as follows:

- **Interstate Concrete** – MAE (140)
  143.33 – 0.667 (IRI)
- **High Speed Concrete** – MAE (150)
  142.31 – 0.615 (IRI)
- **Medium Speed Concrete** – MAE (160)
  141.43 – 0.571 (IRI)
- **Low Speed Concrete** – MAE (170)
  140.67 – 0.533 (IRI)

***CONK*** (Concrete Cracking) – This is a combined index made up of two separately calculated indices for corner breaks (CBRK) and shattered slabs (SHSL). Corner breaks are diagonal cracks in the concrete slabs, where the severity of the distress is determined by the faulting or spalling along the crack (i.e. no spalling or faulting = low severity & spalling or faulting greater than ½ inch = high severity). Shattered slabs are those broken by cracking into four or more pieces. It was decided that shattered slabs were much more critical to the overall concrete slab performance than corner breaks. Therefore, shattered slabs were given a much higher weighting in the combined index. MAEs are in terms of the number of broken/shattered slabs (maximum 40 slabs). Low, Med and High in the equations below, refer to the severity of the distress. The equations related to concrete cracking are listed below.

- CONK = 0.2 CBRK + 0.8 SHSL

**CBRK (Corner Breaks)**

- **Interstate Concrete** – $MAE_L$ (5), $MAE_M$ (4), $MAE_H$ (2)
  100 – (10 (Low) + 12.5 (Med) + 25 (High))

- **High Speed Concrete** - $MAE_L$ (5), $MAE_M$ (4), $MAE_H$ (2)
  100 – (10 (Low) + 12.5 (Med) + 25 (High))

- **Medium Speed Concrete** - $MAE_L$ (10), $MAE_M$ (7), $MAE_H$ (4)
  100 – (5 (Low) + 7.14 (Med) + 12.5 (High))

- **Low Speed Concrete** - $MAE_L$ (10), $MAE_M$ (7), $MAE_H$ (4)

100 – (5 (Low) + 7.14 (Med) + 12.5 (High))

**SHSL (Shattered Slabs)**

- **Interstate Concrete –** MAE (2)
  100 – (25 (#Slabs))

- **High Speed Concrete –** MAE (2)
  100 – (25 (#Slabs))

- **Medium Speed Concrete –** MAE (4)
  100 – (12.5 (#Slabs))

- **Low Speed Concrete –** MAE (4)
  100 – (12.5 (#Slabs))

***FALT*** (Faulting) – Faulting is a measure of the difference in slab elevations as measured by the profile van in faults per mile. Severity is determined by the height of the fault (i.e. less than 0.3 inch = low severity and greater than 0.5 inch = high severity), however; the profile van only records faults that are greater than or equal to 0.1 inch. As above, Low, Med and High represent the severity of the distress. The equations for faulting are listed below.

- **Interstate Concrete –** $MAE_L$ (240), $MAE_M$ (80), $MAE_H$ (20)
  100 – (0.208 (Low) + 0.625 (Med) + 2.5 (High))

- **High Speed Concrete -** $MAE_L$ (240), $MAE_M$ (80), $MAE_H$ (20)
  100 – (0.208 (Low) + 0.625 (Med) + 2.5 (High))

- **Medium Speed Concrete -** $MAE_L$ (400), $MAE_M$ (120), $MAE_H$ (30)
  100 – (0.125 (Low) + 0.417 (Med) + 1.67 (High))

- **Low Speed Concrete -** $MAE_L$ (400), $MAE_M$ (120), $MAE_H$ (30)
  100 – (0.125 (Low) + 0.417 (Med) + 1.67 (High))

***JTSP*** (Joint Spalling) – Joint spalling is a measure of the spalls (surface defects) located at the transverse joints. The severity is determined by the size of the spalls (i.e. less than 3 inches = low severity and greater than 6 inches = high severity). As above, Low, Med and High represent the severity of the distress. The equations for joint spalling are listed below.

- **Interstate Concrete** - $MAE_L$ (24), $MAE_M$ (12), $MAE_H$ (4)
  100 – (2.08 (Low) + 4.17 (Med) + 12.5 (High))

- **High Speed Concrete -** $MAE_L$ (24), $MAE_M$ (12), $MAE_H$ (4)
  100 – (2.08 (Low) + 4.17 (Med) + 12.5 (High))

- **Medium Speed Concrete** - $MAE_L$ (30), $MAE_M$ (16), $MAE_H$ (6)
  100 – (1.67 (Low) + 3.13 (Med) + 8.33 (High))

- **Low Speed Concrete** - $MAE_L$ (30), $MAE_M$ (16), $MAE_H$ (6)
  100 – (1.67 (Low) + 3.13 (Med) + 8.33 (High))

### *Asphalt Indices*

The following indices were developed for asphalt pavements:

RIDE: Roughness based on IRI (average of the left and right wheel path measurements)
RUT: Rutting (longitudinal depressions in the wheel path)
CRCK: Environmental cracking (transverse and longitudinal cracking)
WPCK: Wheel-path cracking (longitudinal cracking due to fatigue)

***RIDE*** (Roughness) – This is measured in the same manner as for concrete pavements. The equations for asphalt pavements are listed below.

- **Interstate Asphalt** – MAE (130)
  115 – 0.500 (IRI)

- **High Speed Asphalt** – MAE (140)
  115.88 – 0.471 (IRI)

- **Medium Speed Asphalt** – MAE (150)
  116.67 – 0.444 (IRI)

- **Low Speed Asphalt** – MAE (160)
  117.37 – 0.421 (IRI)

***RUT*** (Rutting) – Rutting is a measure of the longitudinal depressions (ruts) that develop in the wheel path of asphalt pavements, usually due to heavy truck loading. Rutting is measured with the profile van, which measures changes in elevation across the wheel paths. The rut depth is measured in inches as the average of both wheel paths. The equations for the rutting index are listed below.

- **Interstate Asphalt** – MAE (0.5)
  100 – 100 (Rut Depth)

- **High Speed Asphalt** – MAE (0.625)
  100 – 80 (Rut Depth)

- **Medium Speed Asphalt** – MAE (0.75)
  100 – 66.7 (Rut Depth)

- **Low Speed Asphalt** – MAE (1.25)
  100 – 40 (Rut Depth)

***CRCK*** (Environmental Cracking) – This is a measure of the cracks in the road due to environmental (non-structural) conditions. The index is made up of transverse cracking, block cracking and skin patching. It is calculated the same for all pavement families. The initial value of the cracking index is calculated as follows:

- **Index Value = 50, If…**
  Block cracking/(500 ft) > 100 ft, or
  Skin patching/mile >= 1000 ft

- **Index Value = 70, If…**
  Block cracking/(500 ft) > 50 ft, or
  Skin patching/mile >= 400 ft, or
  Transverse cracks/(500 ft) > 20

- **Index Value = 90, If…**
  Block cracking/(500 ft) > 0 ft, or
  Skin patching/mile >= 200 ft, or
  Transverse cracks/(500 ft) > 10

***WPCK*** (Wheel-Path Cracking) – This is a measure of the cracks that occur directly in the wheel path. Cracks directly in the wheel path are an indication of failure due to vehicle loading (fatigue). The associated cracking, spalling, and pumping determine the severity level of the distress. Low severity is measured as few interconnecting cracks, with no spalling or pumping. Medium severity is measured as interconnecting cracks, with some spalling but no pumping. High severity is measured as interconnecting cracks with moderate or severe spalling where pumping may be present. The equations for the wheel-path cracking index are listed below.

- **Interstate Asphalt** – $MAE_L$ (600), $MAE_M$ (200), $MAE_H$ (30)
  100- (0.083 (Low) + 0.25 (Med) + 1.67 (High))

- **High Speed Asphalt** - $MAE_L$ (650), $MAE_M$ (250), $MAE_H$ (40)
  100- (0.077 (Low) + 0.20 (Med) + 1.25 (High))

- **Medium Speed Asphalt** - $MAE_L$ (700), $MAE_M$ (300), $MAE_H$ (50)
  100- (0.071 (Low) + 0.17 (Med) + 1.0 (High))

- **Low Speed Asphalt** - $MAE_L$ (800), $MAE_M$ (400), $MAE_H$ (80)
  100- (0.0625 (Low) + 0.125 (Med) + 0.625 (High))

***Combined Index***

OCI (Overall Condition Index) – Within the dTIMS pavement management model there is also a combined index, the overall condition index (OCI). The purpose of the index is twofold. The first is to allow the dTIMS model to maximize the benefit to the entire pavement network based upon multiple indices instead of only a single index. This allows the model to compare every section of pavement on a similar scale regardless of pavement type or individual characteristics (i.e. each section could have different individual indices to represent condition). The second reason for having a combined index is to give an indication of the “overall health/condition” of the pavement section. For UDOT, the primary purpose of the OCI is to allow the model to compare pavement sections and maximize the benefit to the network (optimize the pavement condition).

- **OCI** = mean (Asphalt or Concrete Indices)

**Treatments**

The following is a list of treatments that are contained within the dTIMS model. Though somewhat specific in nature, they are meant to represent categories of treatments (individual projects could select treatments that are similar in nature).

- **Concrete Preventive Maintenance**
  (Joint sealing and spot grinding)

- **Concrete Grinding**
  (Diamond grinding)

- **Concrete Minor Rehab**
  (Slab jacking, dowel bar retrofit, slab replacements)

- **Concrete Major Rehab or Reconstruction**
  (Full replacement of pavement structure, crack & seat, rubblization)

- **Chip Seal**
  (Chip seal, slurry seal)

- **Open Graded Seal**
  (Open graded seal, stone matrix asphalt overlay, bonded wearing course)

- **Functional Repair**
  (Patching and thin overlay)

- **Asphalt Minor Rehab**
  (Rotomill & replace, thin overlay)

- **Asphalt Major Rehab**
  (Rotomill & overlay, thick overlay)

- **Asphalt Reconstruction**
  (Full replacement of pavement structure)

**Treatment Costs**

Listed below are the current treatment costs that are contained within the dTIMS model. Each cost is multiplied by a factor of 1.15 to account for additional engineering and other miscellaneous costs. Additional inflation costs are also accounted for within the dTIMS model.

- **Concrete Preventive Maintenance** - $6.50 per square yard
- **Concrete Grinding** - $7.20 per square yard
- **Concrete Minor Rehab** - $13.50 per square yard
- **Concrete Major Rehab or Reconstruction** - $90.00 per square yard
- **Chip Seal** - $1.90 per square yard
- **Open Graded Seal** - $7.10 per square yard
- **Functional Repair** - $8.00 per square yard
- **Asphalt Minor Rehab** - $10.00 per square yard
- **Asphalt Major Rehab** - $30.00 per square yard
- **Asphalt Reconstruction** - $75.00 per square yard

**Treatment Resets**

As a treatment is applied to a section of road, the index values assigned to the section are increased to represent the net value or added pavement life that will be gained by performing the treatment. This increase in the index value is known as a treatment reset. All treatment resets are based upon the previously listed performance curves. The reset values are listed below by treatment.

- **Concrete Preventive Maintenance**
  Ride +25%
  Faulting +25%
  Joint Spalling +25%
  Concrete Cracking +5%

- **Concrete Grinding**
  Ride +65%
  Faulting +65%
  Joint Spalling +25%
  Concrete Cracking +5%

- **Concrete Minor Rehab**
  Ride +65%
  Faulting +65%
  Joint Spalling +35%

| | |
|---|---|
| Concrete Cracking | +35% |

- **Concrete Major Rehab or Reconstruction**
  Reset all indices to 100

- **Chip Seal**

| | |
|---|---|
| Ride | +30% |
| Rutting | +30% |
| Env. Cracking | Reset to 100 |
| Wheel-path Cracking | +10% |

- **Open Graded Seal**

| | |
|---|---|
| Ride | +30% |
| Rutting | +30% |
| Env. Cracking | Reset to 100 |
| Wheel-path Cracking | +10% |

- **Functional Repair**

| | |
|---|---|
| Ride | +35% |
| Rutting | +35% |
| Env. Cracking | Reset to 100 |
| Wheel-path Cracking | +15% |

- **Asphalt Minor Rehab**

| | |
|---|---|
| Ride | Reset to 100 |
| Rutting | Reset to 100 |
| Env. Cracking | Reset to 100 |
| Wheel-path Cracking | +20% |

- **Asphalt Major Rehab**

| | |
|---|---|
| Ride | Reset to 100 |
| Rutting | Reset to 100 |
| Env. Cracking | Reset to 100 |
| Wheel-path Cracking | +65% |

- **Asphalt Reconstruction**
  Reset all indices to 100

**Treatment Triggers**

Treatments are triggered within the dTIMS model whenever certain criteria are met. Those triggered treatments are then recommended and optimized according to the overall benefit cost and budget. In general, UDOT's recommended strategy is to treat a section of pavement no sooner than 8 years for asphalt and 10 years for concrete, due to limited funding constraints. The following is a list of the various treatments and their triggers within the pavement management model.

- **Concrete Preventive Maintenance**
  (RIDE & FALT) >= 70, and
  CONK >= 75, and
  (RIDE <= 90 or FALT <= 90 or JTSP <= 90)

- **Concrete Grinding**
  (RIDE <= 60 or FALT <= 60), and
  CONK >= 60

- **Concrete Minor Rehab**
  (RIDE, FALT and CONK >= 60), and
  (RIDE <= 80 or FALT <= 80 or CONK <= 80 or JTSP <= 80)

- **Concrete Major Rehab or Reconstruction**
  (CONK <= 55 or FALT <= 55)

- **Chip Seal** (also based upon preferred seal type)
  (RIDE, RUT & CRCK >= 70), and
  WPCK >= 75

- **Open Graded Seal** (also based upon preferred seal type)
  (RIDE, RUT & CRCK >= 70), and
  WPCK >= 75

- **Functional Repair**
  (RIDE, RUT or CRCK < 70), or
  WPCK < 75

- **Asphalt Minor Rehab**
  (RIDE <= 50 or RUT <= 70 or CRCK <= 70 or WPCK <= 75), and
  RUT >= 50

- **Asphalt Major Rehab**
  (RIDE <= 30 or RUT <= 50 or CRCK <= 50 or WPCK <= 60)

- **Asphalt Reconstruction**
  WPCK <= 50